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Dewey et al.

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[45] **Date of Patent:** **Jan. 28, 1992**

[54] **FOCUS-ERROR DETECTION USING PRISM-ENHANCED SPOT SIZE MONITORING**

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[73] Assignee: **International Business Machines Corporation**, Armonk, N.Y.

[21] Appl. No.: **511,664**

[22] Filed: **Apr. 20, 1990**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 357,566, May 26, 1989, abandoned.

[51] **Int. Cl.**⁵ **G02B 27/12**; G02B 5/04; G11B 21/10

[52] **U.S. Cl.** **359/640**; 359/618; 359/837; 369/44.14; 369/44.23

[58] **Field of Search** 350/170–174, 350/370, 376, 378, 384, 401–405; 250/201, 202, 216; 369/44–46, 112

[56] **References Cited**

U.S. PATENT DOCUMENTS

Re. 24,972	4/1961	Luboshez	350/424
4,358,200	11/1982	Hgemskerk	350/172
4,635,244	1/1987	Gotoh	350/402
4,689,780	8/1987	Ohara et al.	350/402
4,719,614	1/1988	Leterme et al.	369/110
4,725,725	2/1988	Ando	369/44.14
4,793,696	12/1988	Suh	350/370
4,888,752	12/1989	Arai	250/201.5
4,920,527	4/1990	Maeda	369/44.23
4,965,785	10/1990	Tadokoro et al.	369/112

FOREIGN PATENT DOCUMENTS

2107483	4/1983	United Kingdom	350/170

OTHER PUBLICATIONS

"Design Consideration of Optical Pregroove Dimensions", Yamamoto et al, Optical Society of America, 1985, pp. 1–4.

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Assistant Examiner—Thong Nguyen
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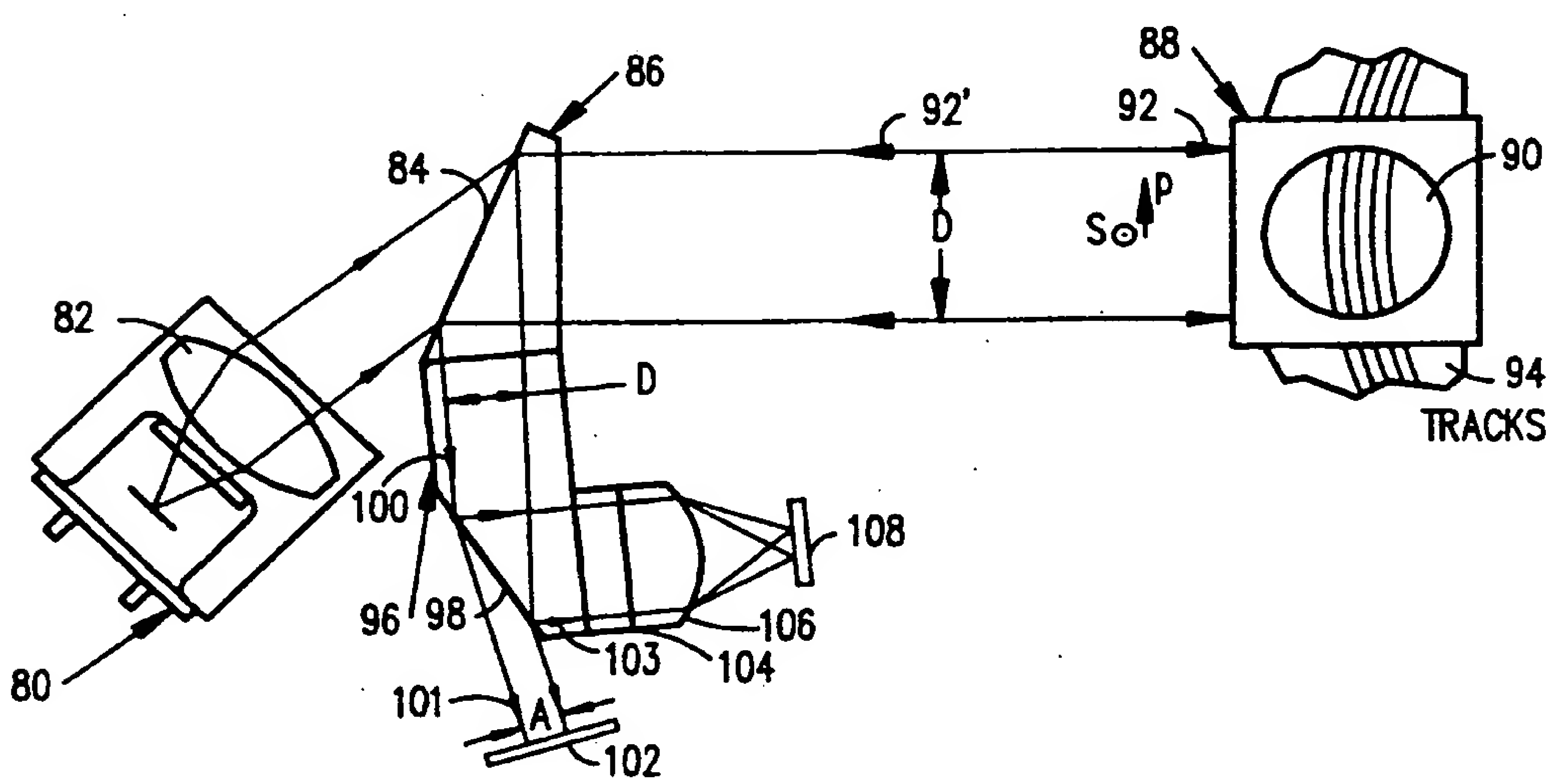
[57] **ABSTRACT**

An apparatus and method is described for detecting focus errors in an optical head by positioning a prism in the optical path of a return light beam reflected from an optical recording medium. The prism reduces the beam in one dimension by a factor of M and concurrently increases the divergence/convergence angle associated with a focus-error of the beam by a factor of M in this dimension, thereby desirably enhancing the focus error signal by a factor of M^2. A focus error is detected by a segmented photodetector having inner and outer photosensitive regions. The photodetector generates an electrical signal indicative of the focus error from the difference in light intensities at the inner and outer regions. The photodetector preferably is segmented in such manner as to also provide a track error signal.

11 Claims, 3 Drawing Sheets



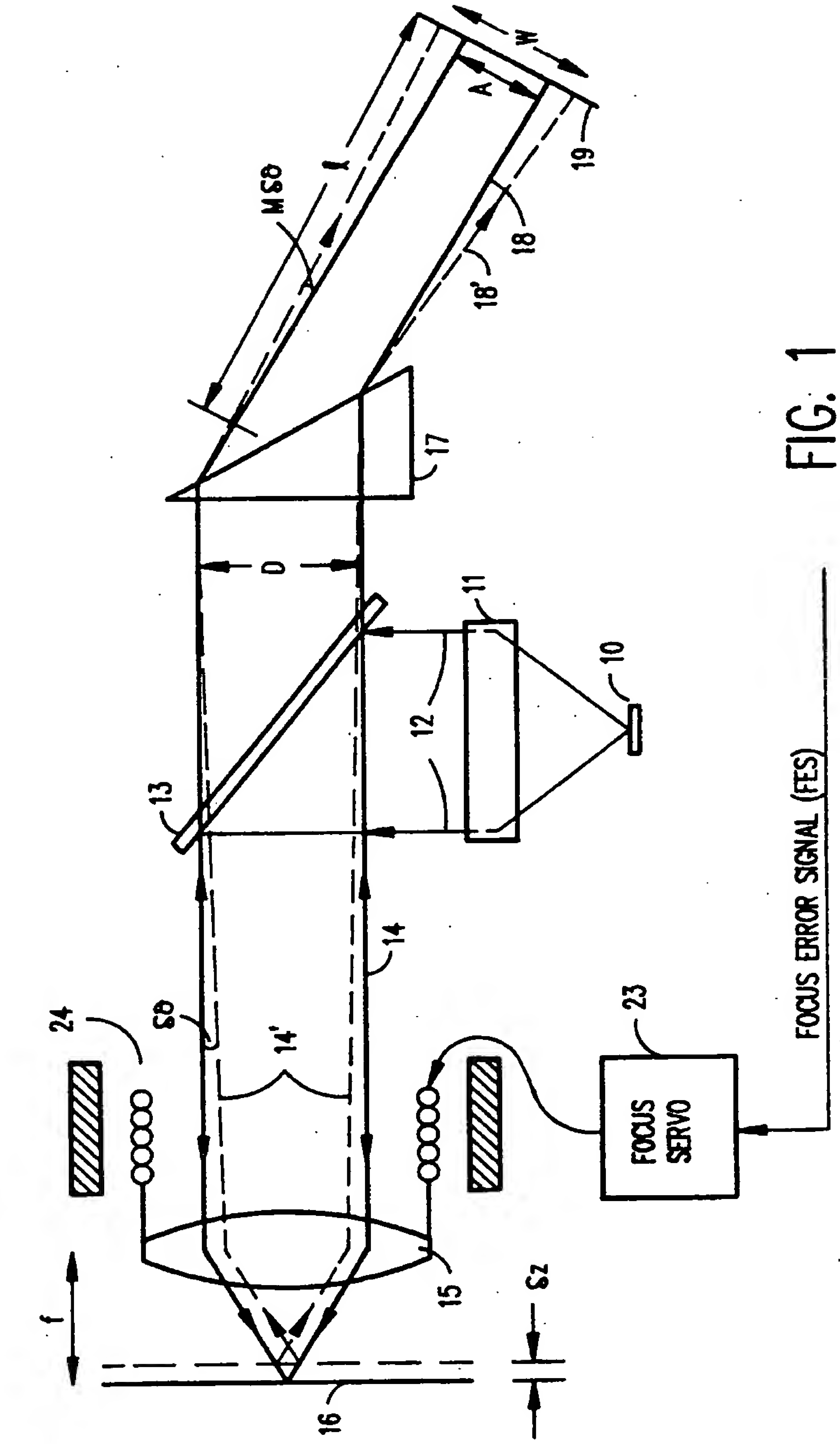

FOCUS SERVO
FOCUS ERROR SIGNAL (FES)
10
11
12
13
14
14'
15
16
17
18
18'
19
23
24
D
A
W

FIG. 1

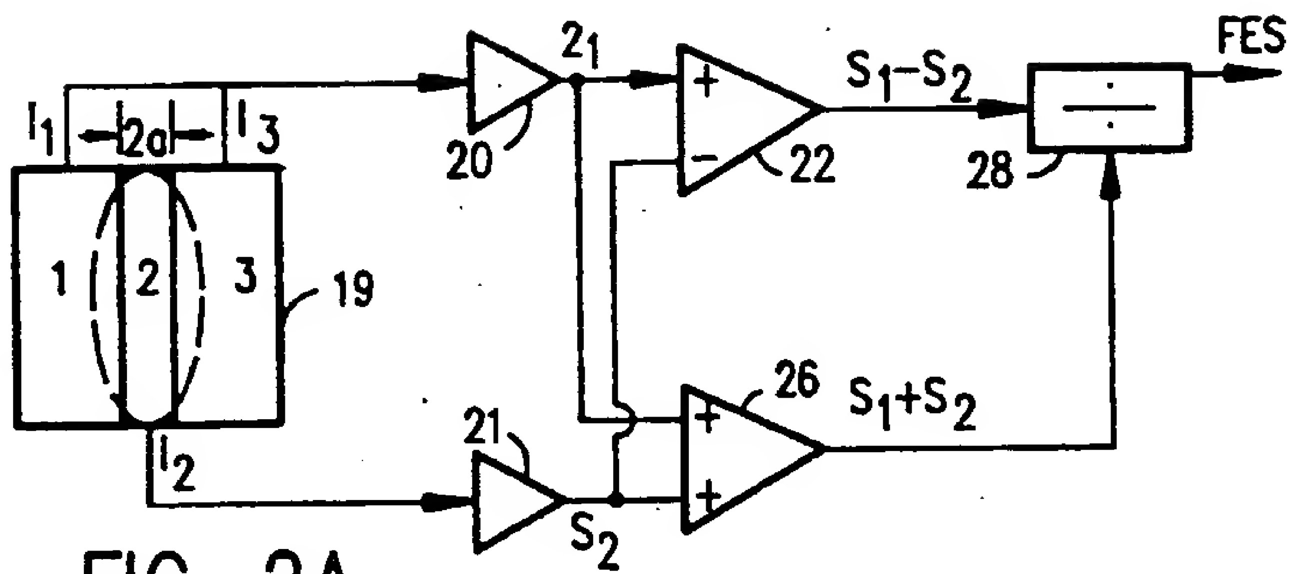


FIG. 2A

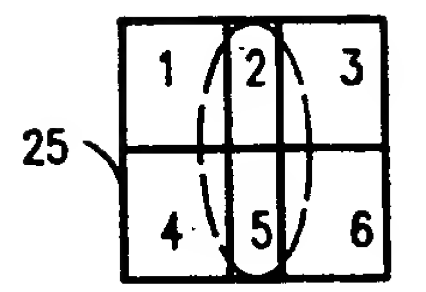


FIG. 2B

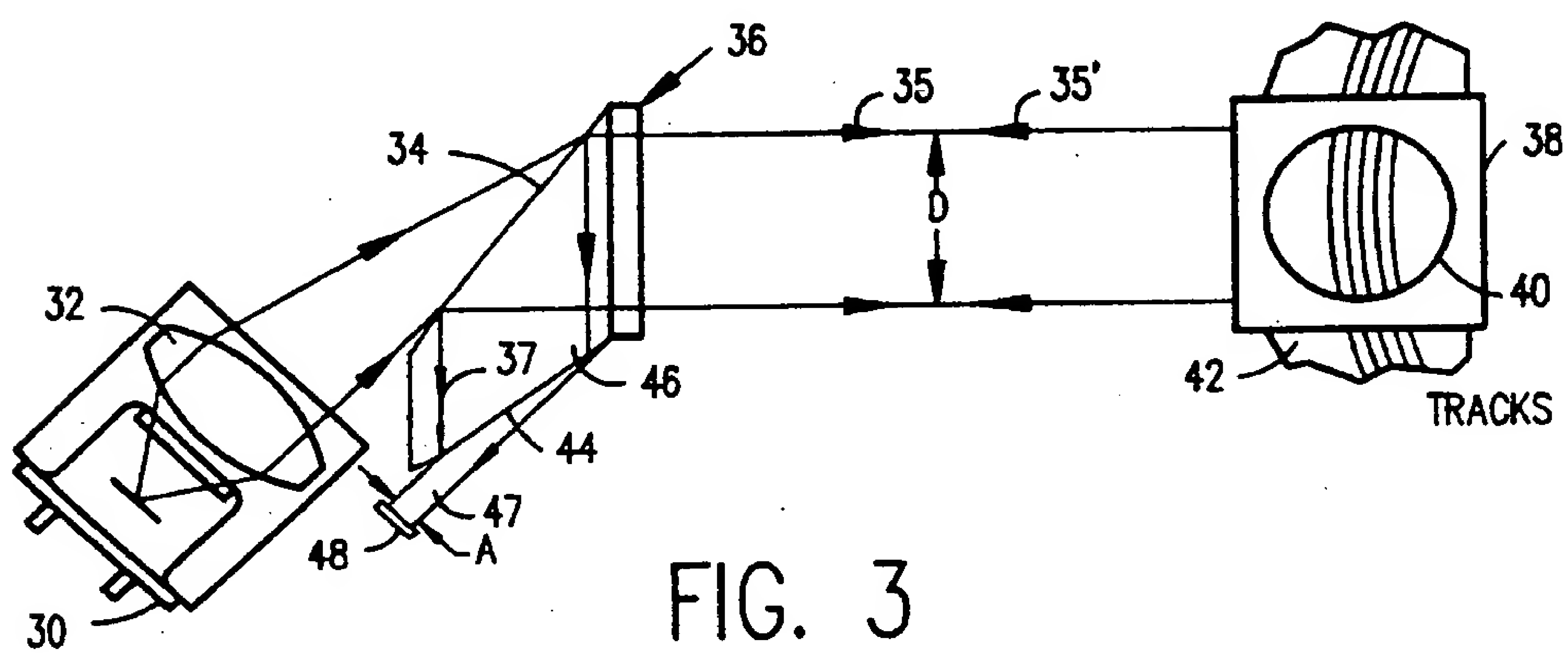


FIG. 3

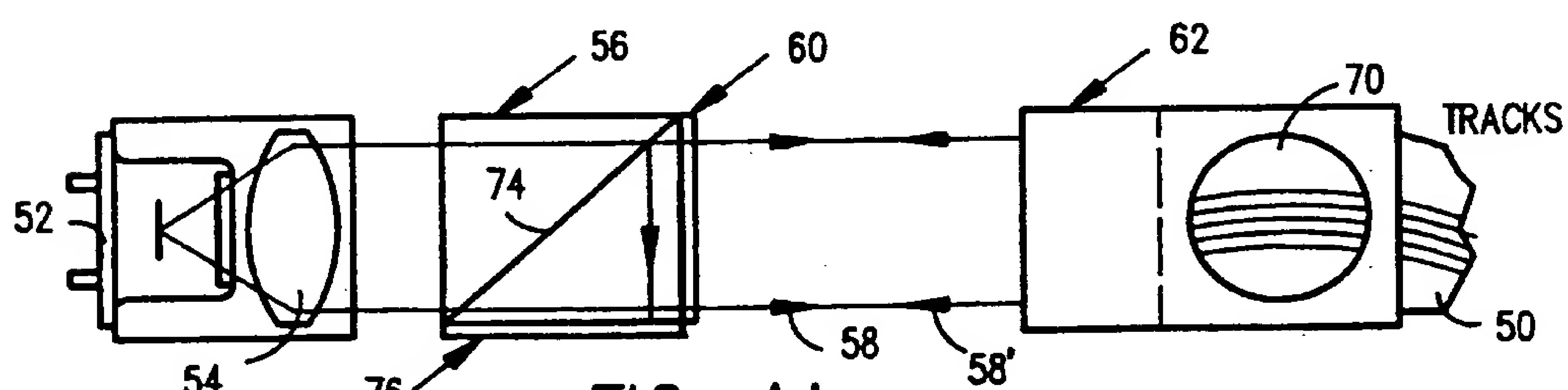
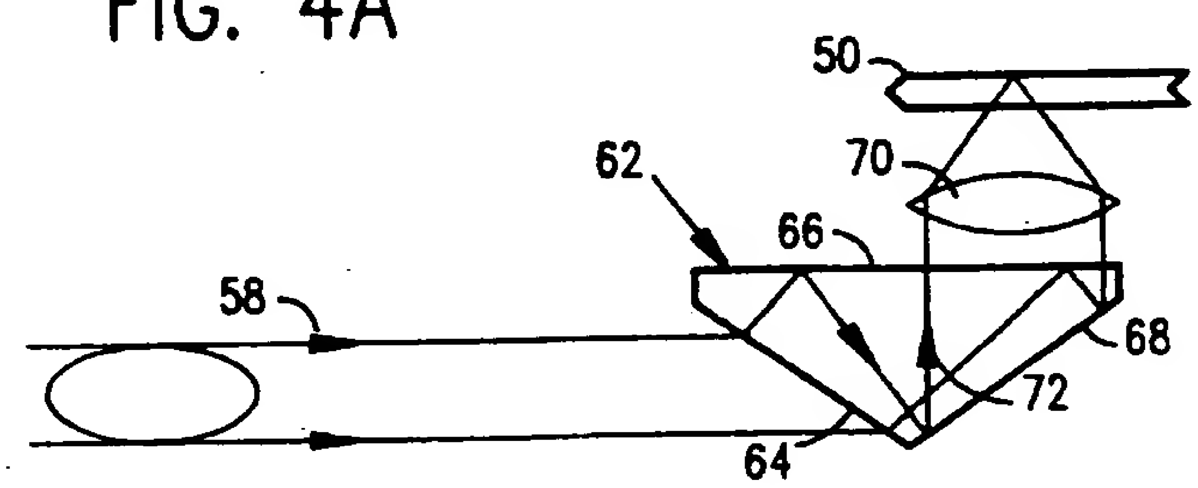
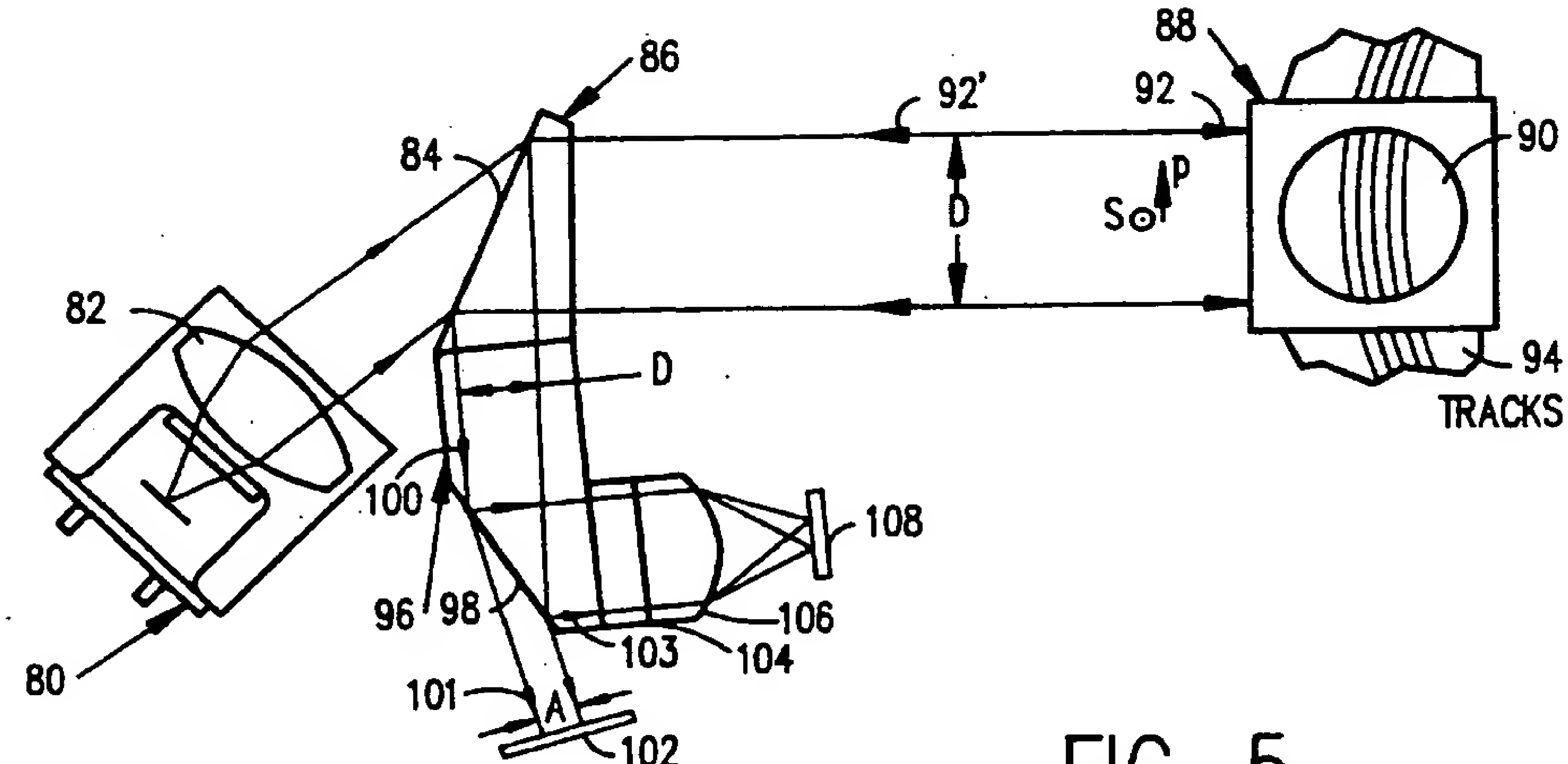


FIG. 4A

FIG. 4B





86
84
92'
92
88
90
D
S
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82
D
100
108
96
98
103
106
104
80
101
A
102
94
TRACKS

FIG. 5

FOCUS-ERROR DETECTION USING PRISM-ENHANCED SPOT SIZE MONITORING

This is a Continuation-in-Part of application Ser. No. 07/357,566, filed May 26, 1989, now abandoned.

TECHNICAL FIELD

This invention relates to methods and means for detecting focus errors in optical heads adapted to read and write data on optical recording media, and more particularly relates to improved means for generating a focus error signal for use as focus on a surface.

BACKGROUND OF THE INVENTION

Focus-error detection methods heretofore used for optical storage applications generally employ a knife edge, an astigmatic lens or a critical angle prism. These techniques require very critical alignment of these optical elements and of a segmented photodetector.

Published European patent application EP 0164687 discloses a detection technique wherein a laser beam reflected from an optical disk is directed through an objective lens to a prism that reduces beam width in one dimension by a factor M and delivers an elliptical beam to a knife-edge-type focus error detection system. This application claims that the use of the prism increases the focus error signal by a factor of M compared to the standard knife edge technique without a prism.

The Digest of the Topical Meeting on Optical Data Storage, Oct. 15–17, 1985 at Washington, D.C., includes Paper THCC2-1 by Yamamoto et al. entitled "Design Consideration of Optical Pregroove Dimensions". This paper shows a six-element photodetector to detect the far field spot size variations associated with a focus error.

There is a need for a very sensitive focus-error detection technique that will provide, with relatively few components, a significant enhancement of the focus-error signal and provide a large beam size that only requires an uncritical alignment of a segmented photodetector in one dimension.

SUMMARY OF THE INVENTION

Toward this end and according to the invention, an apparatus and method are provided for detecting focus errors in an optical head by positioning a prism in the optical path of a return light beam reflected from an optical recording medium. The prism reduces the beam in one dimension by a factor of M and concurrently increases the divergence/convergence angle associated with a focus-error of the beam by a factor of M in said dimension, thereby desirably enhancing the focus error signal by a factor of M^2. A focus error is detected by a segmented photodetector having inner and outer photosensitive regions, such as shown in the Yamamoto et al. paper. The photodetector generates an electrical signal indicative of the focus error from the difference in light intensities at the inner and outer regions. The photodetector preferably is segmented in such manner as to also provide a track error signal.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram that illustrates the principle of the invention;

FIGS. 2A shows a schematic diagram of a segmented photodetector and associated circuit of the present invention;

FIG. 2B shows a schematic diagram of an alternative segmented photodetector of the present invention;

FIG. 3 illustrates an optical head according to one embodiment of the invention for use with read-only, write-once or phase-change optical disks;

FIG. 4A shows a tip view of an embodiment for use with an optical disk drive employing a swing arm actuator;

FIG. 4B shows a partial side view of the embodiment of FIG. 4A and;

FIG. 5 illustrates an embodiment for use with magneto-optic disks.

DESCRIPTION OF PREFERRED EMBODIMENTS

General

The principle of the invention is best illustrated in FIG. 1. The output of a diode laser **10** is passed through a circularizer/collimator system **11** to provide a collimated beam **12**. On reflection from a beam splitter **13**, beam **12** becomes beam **14**. Beam **14** is focused by a lens **15** onto surface **16** of an optical recording medium. When surface **16** is at the focus of lens **15**, the collimated beam **14** from beam splitter **13** to lens **15** is retroreflected on itself and, as return beam **14**, is transmitted by beam splitter **13** to a prism **17**. Prism **17** refracts beam **14** as beam **18**, which is directed without obstruction to a photodetector **19**. The full cross-sectional beam pattern of beam **18** falls on photodetector **19**. Beam **18** has an intensity pattern of elliptical configuration, with a major axis equal to D and a minor axis A. Prism **17** reduces the width of beam **14** by a factor of M (which is defined as M =D/A) to that of refracted beam **18**.

Assume now that the surface **16** is displaced from the focus of lens **15** by an amount δz. Under this assumed condition, the beam **14'** reflected from surface **16** will, after passing through lens **15**, diverge with an angle $\delta\theta$, in which

$$\delta\theta = D\delta z/f^2 \quad (1)$$

where f is the focal length of lens **15**.

If δz is negative, then $\delta\theta$ will be negative and the beam **14'** will converge. The following analysis considers the case of δz being positive, but when δz is small, the same analysis is valid for a diverging or converging beam **14'**.

The refracted beam **18'** emerging from prism **17** has a divergence angle of $M\delta\theta$; and the width W of said beam on detector **19** is now given by

$$W \simeq A + 2lM\delta\theta \quad (2)$$

where l is the distance from prism **17** to photodetector **19**.

Using equation (1), one obtains

$$\begin{aligned} W &\simeq A + 2lMD\delta z/f^2 \\ &\simeq A + 2lM^2A\delta z/f^2 \end{aligned}$$

or

$$\delta W/\delta z = (W - A)/\delta z = 2lM^2A/f^2 \quad (3)$$

It will thus be seen that, by inserting prism **17** in the path of the return beam **14'** from surface **16**, the change in beam width δW indicative of a focus error δz is en-

hanced by a factor M^2. M is determined by the apex angle of prism **17**, and by the refractive index of the material from which it is made. M may be made arbitrarily large; however, the tolerance on alignment of the system becomes increasingly tight as M increases. A practical maximum value of M for a single prism **17** is approximately equal to five; however, several prisms may be used in series and the resultant factor M would then be the product of the values of M for each prism.

As illustrated in FIG. **2A**, photodetector **19** comprises three photosensitive striped areas **1,2,3**. The dotted oval represents the full cross-sectional beam pattern which beam **18** makes on photodetector **19**. Let I_1, I_2, I_3 be the electrical signals generated by the light incident on these photosensitive areas **1,2,3**, respectively.

Signals I_1 and I_3 are summed and amplified at amplifier **20** to provide output signal S_1, whereas signal I_2 is amplified at amplifier **21** to provide output signal S_2. S_1 equals S_2 when the beam **14** is in focus. Signals S_1 and S_2 are supplied to a differential amplifier **22** and a summing amplifier **26** whose outputs are supplied to divider circuit **28**. The bandwidth of amplifiers **20, 21, 22** and **26** are sufficiently in excess of the focus-servo bandwidth, (which is typically less than 10kHz), such that the phase differences between the outputs of amplifiers **22** and **26** are negligible. The output of the divider circuit **28** is the focus error signal, FES.

$$FES = \frac{S_1 - S_2}{S_1 + S_2} \tag{4}$$

The focus error signal is applied to a focus servo control system **23** (FIG. **1**). As illustrated, system **23** comprises conventional means, such as a voice coil driver, for adjusting the current in a coil **24** of a voice coil motor and thereby adjusting the position of lens **15** relative to surface **16**. A typical servo system is shown in European patent application EP0164687.

In a diffraction-limited optical system the intensity profile of beam **18** will be Gaussian, that is:

$$-8x^2/W^2 \tag{5}$$

The width $2a$ of area **2** of detector **19** is chosen such that when disk surface **16** is at the focus of lens **15**, one half of the light incident on detector **19** falls on area **2**, and the other half falls on areas **1** and **3**.

The total power P in beam **18** is given by:

$$P = \int_{-\infty}^{\infty} I_o e^{-8x^2/W^2} dx = \frac{\sqrt{2\pi}}{4} W I_o \tag{6}$$

and the power on area **2** of detector **19** is:

$$P_2 = \int_{-a}^{a} I_o e^{-8x^2/W^2} dx \tag{7}$$

which, when $\delta z = 0$ and $W = A$, is equal to $P/2$ when $a = 0.169A$.

In order to evaluate the sensitivity of the FES to changes in the focus position dz of lens **15**, we need to find the relative change of S_2 with dz. Since S_2 is proportional to I_2 and I_2 is proportional to P_2, the quantity of interest is:

$$\frac{1}{P_2}\frac{dP_2}{dz} = \frac{1}{P_2}\frac{dP_2}{dW}\frac{dW}{dz}$$

Using equations (3) and (7)

$$\frac{1}{P_2}\frac{dP_2}{dz} = \frac{2}{P}\frac{d}{dW}\left[\frac{4P}{\sqrt{2\pi}\,W}\int_{-a}^{a} e^{-8x^2/W^2} dx\right]\frac{2lM^2A}{f^2}$$

$$= \frac{16lM^2A}{\sqrt{2\pi}\,f^2}\frac{d}{dW}\left[\frac{1}{W}\int_{-a}^{a} e^{-8x^2/W^2} dx\right]$$

the derivative is evaluated as:

$$= \frac{1}{W}\int_{-a}^{a}\frac{d}{dW}(e^{-8x^2/W^2})dx - \frac{1}{W^2}\int_{-a}^{a} e^{-8x^2/W^2} dx$$

$$= \frac{1}{W}\int_{-a}^{a}\frac{16x^2}{W^3} e^{-8x^2/W^2} dx - \frac{1}{W^2}\int_{-a}^{a} e^{-8x^2/W^2} dx$$

$$= \frac{1}{W^2}\int_{-a}^{a} -x\frac{d}{dx}(e^{-8x^2/W^2})dx - \frac{1}{W^2}\int_{-a}^{a}(e^{-8x^2/W^2})dx$$

$$= \frac{1}{W^2}\left[-x\, e^{-8x^2/W^2}\right]_{-a}^{a}$$

$$= -\frac{2a}{W^2} e^{-8a^2/W^2}$$

When $\delta z = 0$, $a = 0.169A$, and $W = A$, the above quantity is equal to $-0.269/A$. Thus

$$\frac{1}{P_2}\frac{dP_2}{dz} = \frac{-16lM^2}{\sqrt{2\pi}\,f^2}(0.269) = \frac{-1.72lM^2}{f^2}$$

For typical values of l(50 mm) and f(4 mm) and with no prism (M=1) as in the prior art (see Yamamoto, et al.), this quantity is equal to 5.4/mm. A large focus error δz of 0.001 mm would create a change in P_2, and hence in S_2, of only 0.54%. Since the change in S_1 is equal and opposite to that of S_2, it follows from equation (4) that the FES, which has a range of ±1, would be only 0.0108.

Incorporating a prism with M=5 according to the principles of this invention would increase the FES to 0.264, an increase by a factor of 25 in the sensitivity of the focus servo loop.

The preferred configuration of the photodetector is shown in FIG. **2B**. Photodetector **25** includes six photosensitive areas **1–6** for generating electrical signals I_1–I_6, respectively. The focus error signal is given by

$$FES = \frac{S_1 - S_2}{S_1 + S_2}$$

and the track error signal by

$$TES = \frac{S_3 - S_4}{S_3 + S_4}$$

where

$$S_1 = k(I_1 + I_3 + I_4 + I_6)$$
$$S_2 = k(I_2 + I_5)$$
$$S_3 = k(I_1 + I_2 + I_3)$$
$$S_4 = k(I_4 + I_5 + I_6)$$

where k is the gain of amplifiers 20 and 21.

The manner in which the track error signal is used to adjust track error is conventional and forms no part of the present invention. FIG. 2B is included merely to show that applicants' method and means for detecting and correcting focus errors is compatible with and desirably used in conjunction with a photodetector like photodetector 25 that generates both focus error and track error signals.

FIG. 3

As illustrated in FIG. 3, the invention according to this embodiment comprises an optical head especially suitable for use with read-only, write-once or phase-change optical disks. A laser 30 emits a beam that is collimated by a lens 32 and circularized by refraction at surface 34 of a prism 46. Surface 34 has a polarizing beam splitter (PBS) coating. The beam 35 is directed through a quarter-wave plate 36 to a beam bender 38 and a lens 40 that focuses said beam onto a selectable track on an optical disk 42. The beam 35' reflected from disk 42 returns through the wave plate 36 and is reflected as beam 37 from surface 34 toward surface 44 of prism 46. Refraction of beam 37 at surface 44 reduces the width of said beam by a factor of M from D to A and directs this elliptical beam 47 to a photodetector 48 that preferably is segmented as shown in FIG. 2A or 2B. The full unobstructed cross-sectional beam pattern of beam 47 falls on photodetector 48.

If, as illustrated in FIG. 3, the disk 42 is in focus, then the return beam 35' will coincide with the beam 35, and the beam width at the photodetector 48 will be equal to A. If, however, disk 42 is out of focus, then the return beam 35' will diverge or converge from the beam 35, and cause the width of the beam to the photodetector 48 to be greater or smaller than A. This effect is analogous to the divergence of beam 18' as shown in FIG. 1. Photodetector 48 is connected to circuitry similar to that shown in FIG. 2A and a FES is generated. The position of lens 40 relative to the surface of the disk 42 is adjusted in response to this FES by suitable servo means similar to that shown in FIG. 1 as necessary to put the disk in focus.

FIG. 4

FIGS. 4A and 4B illustrate another embodiment of an optical head for use with read-only, write-once or phase-change disks. According to this embodiment, the general orientation of the head is parallel to the tracks on a disk 50. This head is therefore most easily adapted to a disk drive that employs a swing-arm actuator. A laser 52 (FIG. 4A) emits a beam that is collimated by a lens 54 and directed to and through a PBS 56 without deflection or reflection. Beam 58 from PBS 56 is elliptical in cross section, with a width D in one dimension and a width A in a direction orthogonal thereto. This beam 58 passes through a quarter-wave plate 60 and is directed to a prism assembly 62. At a first surface 64 of prism assembly 62, beam 58 is circularized, then reflected by total internal reflection (TIR) from another surface 66 to and off a reflective surface 68 to an objective lens 70 that focuses the resultant beam 72 onto the disk 50. Beam 72 is reflected from the disk as reflected beam 58'. In this embodiment, refraction at surface 64 accomplishes the two functions of circularizing the beam 58 going to the disk and enhancing the focus error signal. Beam 58', which again is elliptical in cross section, is reflected by a surface 74 of the PBS 56 and directed to a photodetector 76 that preferably is segmented as shown in FIG. 2A or 2B. The full unobstructed beam pattern of beam 58' falls on photodetector 76.

If, as illustrated in FIG. 4, the disk 50 is in focus, then the return beam 58' will coincide with the beam 58, and the beam width at the photodetector 76 will be equal to A. If, however, the data on disk 50 is out of focus, then the return beam 58' will diverge from the beam 58, and cause the width of the beam to the photodetector 76 to be greater than A. This effect is analogous to the divergence of beam 18' as shown in FIG. 1. Photodetector 76 is connected to circuitry similar to that shown in FIG. 2A and a FES is generated. The position of lens 70 relative to the surface of the disk 50 is adjusted in response to this FES by suitable servo means similar to that shown in FIG. 1 as necessary to put the disk in focus.

This embodiment requires that the expansion/compression ratio M of prism assembly 62 must be matched to the emission pattern of laser 52.

FIG. 5

FIG. 5 illustrates still another embodiment of an optical head for use with magneto-optic disks. A laser 80 emits a beam that is collimated by a lens 82, circularized by refraction at surface 84 of a prism 86 and directed towards a beam bender 88 and an objective lens 90. Surface 84 is a partially polarizing beam splitter surface that directs a fraction of the p-polarized component of beam 92' as reflected from a selected track on disk 94, and substantially all of the s-polarized component of said beam to surface 98 of a prism 96 as a beam 100. Surface 98 is also a partially-polarizing beam splitter surface. Surface 98 refracts a fraction of the p-polarized component of beam 100 as a beam 101 to a servo photodetector 102 preferably segmented as shown in FIG. 2A or 2B. The full cross-sectional beam pattern of beam 101 falls on photodetector 102. This refraction at surface 98 causes a reduction in one dimension of beam 100 by a factor of M and concurrently increases the divergence/convergence angle associated with said beam by the factor M in said dimension. Surface 98 also directs a fraction of the p-polarized component of beam 100 as well as substantially all of the s-polarized component of beam 100 as a beam 103 to a Wollaston prism 104, converging lens 106 and data detector 108. The function of the Wollaston prism in detecting the data on a magneto-optic disk is well known in the art and does not form part of the present invention.

If, as illustrated in FIG. 5, the disk **94** is in focus, then the return beam **92'** will coincide with the primary beam **92**, and the beam width at the photodetector **102** will be equal to A. If, however, the disk **94** is out of focus, then the return beam **92'** will diverge from the beam **92**, and cause the width of the beam to the photodetector **102** to be greater than A. This effect is analogous to the divergence of beam **18'** as shown in FIG. **1**. Photodetector **102** is connected to circuitry similar to that shown in FIG. **2A** and a FES is generated. The position of lens **90** relative to the surface of the disk **94** is adjusted in response to this FES by suitable servo means similar to that shown in FIG. **1** as necessary to put the disk in focus.

It will now be seen that, in each of the configurations shown in FIGS. **3–5**, unlike those taught by the prior art, the focus error signal is desirably enhanced by a factor of M^2.

While the invention has been shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made without departing from the spirit and scope of the invention, and the invention is therefore not to be limited except as defined in the claims.

What is claimed is:

1. An apparatus for detecting a focus-error in an optical head adapted to read and/or write data on an optical recording medium, comprising:

a light source for providing a primary light beam to said medium;

a prism positioned in an optical path of a return light beam reflected from said medium for reducing said return light beam in one dimension by a factor of M and concurrently increasing the divergence/convergence angle of said return light beam by a factor of M in said dimension, whereby a change in said dimension of said return light beam indicative of said focus-error of said head is enhanced by a factor of M^2;

a photodetector located in said optical path for receiving an unobstructed return light beam from the prism, the photodetector having a first, second and third photosensitive areas located proximate one another along said dimension of said return beam; and

a circuit connected to the photodetector for comparing the sum of the amount of light at said first and third areas with the amount of light at the second area and generating a focus-error signal responsive thereto.

2. The apparatus of claim **1**, wherein said second photosensitive area is centered between the first and third photosensitive areas such that the focus-error signal generated is zero when the sum of the amount of light at the first and third photosensitive areas equals the amount of light at the second photosensitive area.

3. The apparatus of claim **2**, wherein said second photosensitive area is in the form of a strip between said first and third photosensitive areas and said first, second and third areas are further divided in a direction perpendicular to the stripe to create three upper and three lower photosensitive areas.

4. The apparatus of claim **1**, further including:

a focus lens located in the optical path of said primary beam for directing said primary beam onto said medium; and

servo means connected to the photodetector and the focus lens for adjusting the focus lens relative to the medium responsive to said focus-error signal.

5. An apparatus for detecting a focus-error in an optical head adapted to read and/or write data on an optical recording medium, comprising:

a light generation means for providing a primary beam of collimated light;

a prism having one surface for circularizing said primary beam;

a quarter-wave plate for receiving said primary beam from said prism;

a lens for focusing said primary beam from the quarter-wave plate onto said medium;

said prism being positioned in the optical path of a return light beam reflected from the medium for reducing said return light beam in one dimension by a factor M and concurrently increasing the divergence/convergence angle of said return light beam by a factor of M in said dimension, whereby a change in said dimension of said return light beam indicative of said focus-error of said head is enhanced by a factor M^2;

a photodetector located in said optical path for receiving an unobstructed return light beam from the prism, the photodetector having a first, second and third photosensitive areas located proximate one another along said dimension of said return beam; and

a circuit connected to the photodetector for comparing the sum of the amount of light at the first and third areas with the amount of light at the second area and generating a focus-error signal responsive thereto.

6. An apparatus for detecting a focus-error in an optical head adapted to read and/or write data on an optical recording medium, comprising:

a light generation means for providing a primary beam of collimated light;

a quarter-wave plate for receiving said primary beam;

a prism having one surface for circularizing the primary beam from the quarter-wave plate, a second surface from which the circularized light is reflected by total internal reflection, and a third surface which is reflective;

a lens for focussing the beam reflected from said third surface onto the medium;

said prism being positioned in the optical path of a return light beam reflected from the medium for reducing said return light beam in one dimension by a factor of M and concurrently increasing the divergence/convergence angle of said return light beam by a factor of M in said dimension, whereby a change in said dimension of said return light beam indicative of said focus-error of said head is enhanced by a factor of M^2;

a polarizing beamsplitter for receiving said return light beam from said prism;

a photodetector located in said optical path for receiving an unobstructed return light beam from the prism, the photodetector having a first, second and third photosensitive areas located proximate one another along said dimension of said return beam; and

a circuit connected to the photodetector for comparing the sum of the amount of light at the first and third areas with the amount of light at the second

area and generating a focus-error signal responsive thereto.

7. A method for detecting a focus-error in an optical head to which a light beam is directed for reading and/or writing data on an optical recording medium, the steps comprising:

positioning a prism in an optical path of a return light beam reflected from said medium for reducing said return light beam in one dimension by a factor of M and concurrently increasing the divergence/ convergence angle of said return light beam by a factor of M in said dimension, whereby a change in said dimension of said return light beam indicative of said focus-error of said head is enhanced by a factor M^2;

providing a photodetector located in said optical path for receiving an unobstructed return light beam from the prism, the photodetector having a first, second and third photosensitive areas located proximate one another along said dimension of said return light beam; and

comparing the sum of the amount of light at the first and third photosensitive areas with the amount of light at the second photosensitive area and generating a focus-error signal responsive thereto.

8. The method of claim 7, wherein said second photosensitive area is centered between the first and third photosensitive areas such that the focus-error signal generated is zero when the sum of the amount of light at the first and third photosensitive areas equals the amount of light at the second photosensitive area.

9. The method of claim 8, wherein said second photosensitive area is in the form of a strip between said first and third photosensitive areas and said first, second and third areas are further divided in a direction perpendicular to the stripe to create three upper and three lower photosensitive areas.

10. The method of claim 7, further including the step of adjusting the position of a focussing lens within the optical path in response to said focus-error signal as necessary to cause the sum of the amount of light at the first and third photosensitive areas to equal the amount of light at the second photosensitive area.

11. An apparatus for detecting a focus-error in an optical head adapted to read and/or write data on an optical recording medium, comprising:

a light generation means for providing a primary beam of collimated light;

a first prism for circularizing said primary beam by refraction;

a lens for focussing said primary beam from the first prism on to the medium;

a second prism;

said first prism being positioned in the optical path of a return light beam reflected from the medium, the first prism having a partially polarizing beamsplitter surface for directing a fraction of a p-polarized component of said return beam and substantially all of a s-polarized component of said return light beam to the second prism;

said second prism having a partially polarizing beamsplitter surface for refracting a fraction of the p-polarized component of said return light beam from the first prism, and said second prism reducing said return light beam in one dimension by a factor of M and concurrently increasing the divergence/convergence angle of said return light beam by a factor M in said dimension, whereby a change in said dimension of said return light beam indicative of said focus-error of said head is enhanced by a factor of M^2;

a photodetector located in said optical path for receiving an unobstructed return light beam from the second prism, the photodetector having a first, second and third photosensitive areas located proximate one another along said dimension of said return beam; and

a circuit connected to the photodetector for comparing the sum of the amount of light at the first and third photosensitive areas with the amount of light at the second photosensitive area and generating a focus-error signal responsive thereto.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 5,084,783

DATED : January 28, 1992

INVENTOR(S) : Dewey, et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Claims

CLAIM 3, Column 7, Line 60, replace "strip" with --stripe--.

CLAIM 9, Column 9, Line 34, replace "strip" with --stripe--.

Signed and Sealed this

First Day of June, 1993

Attest:

Michael K. Kirk

MICHAEL K. KIRK

Attesting Officer

Acting Commissioner of Patents and Trademarks

D1

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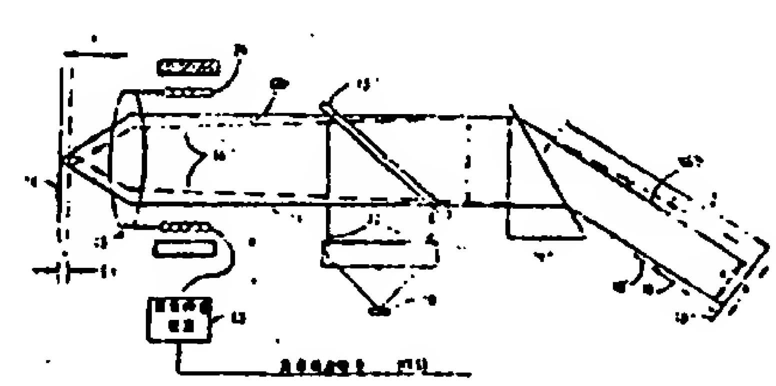
[54]发明名称 利用棱镜增强光斑尺寸监测法探测聚焦误差

[57]摘要

本发明叙述了在光记录介质反射的返回光束的光路上放置一个棱镜,以探测光头聚焦误差的方法和装置。该棱镜在一个方向上将光束宽度压缩 M 倍,同时在所述方向上将与该光束聚焦误差相关的发散/会聚角增加 M 倍,从而可望将聚焦误差信号增强 M^2 倍。聚焦误差由一具有内外光敏区的分区光探测器探测。该光探测器由内外区光强差产生表示聚焦误差的电信号。光探测器最好以也能提供轨迹误差信号的方式分区。



权 利 要 求 书

1．适用于在光学记录介质上读和／或写数据光头中的聚焦误差探测装置，其特征在于：

产生对应于聚焦误差的电信号的光探测器，和

置于经所述介质反射的返回光束光路中的棱镜，用以将光束截面在一个方向上压缩M倍，同时在所述方向上将与所述光束聚焦误差相关的发散／会聚角增加M倍，因而把聚焦误差信号增强M^2倍。

2．权利要求1中的装置，其特征在于：所述光探测器包含内、外光敏区，并根据所述内、外光敏区光强差产生电信号。

3．权利要求2中的装置，其特征在于一个内区处于二个外光敏区之间，使得当在内区探测到的光强等于在二个外区探测到的光强之和时，所产生的聚焦误差信号为零。

4．权利要求2中的装置，其特征在于光探测器具有一个条形内光敏区，它处在二个外光敏区之间，而所述各区在垂直于条形的方向上分割成三个上光敏区和三个下光敏区，由此另一个表示轨迹误差的电信号可由所述上、下区光强之差产生。

5．权利要求1中的装置，其特征为：

提供初始平行光束的装置，和

一聚焦透镜将所述初始光束对准在介质上，使得反射光束当所述透镜聚焦在介质上时与初始光束重合。

6．权利要求5中的装置，其特征为：

包括伺服装置在内的各装置，能响应返回光束相对于初始光束的发射或会聚所产生的表示聚焦误差的聚焦误差信号，用于调整透镜和介质的相对位置以消除聚焦误差。

7。一个用于包含大量轨迹以存储数据的光盘的光头，其特征在于：

提供平行光束的装置，

包含起偏分束器并能使光通过折射成为圆形截面的棱镜装置和

包含1／4波片、光束弯头和透镜用以把圆截面光束聚焦在选定轨迹上的装置。

所述棱镜装置放在由光盘反射的返回光束的光路中，用以在一个方向上将光束宽度压缩M倍，并且同时在所述方向上将与所述光束聚焦误差相联系的发散／会聚角增加M倍，因而将表示聚焦误差的电信号增强M^2倍。

8。一个用于包含大量轨迹以存储数据的光盘的光头，其特征在于：

提供平行光束的装置。

一个1／4波片。

包含一个把通过1／4波片的光束截面变为圆形的表面、把圆形截面光束内部全反射的第二个表面和做为反射面的第三个表面的棱镜装置。

将所述第三表面反射的光束聚焦在光盘上的透镜装置。

产生一个相应于所述光束聚焦误差的信号的光探测器。

所述棱镜装置放置在由光盘反射的返回光束的光路上，用以在一个

个方向上将光束宽度压缩M倍同时在所述方向将所述光束与聚焦误差相关的发散／会聚角增加M倍，因而使所述信号增强M^2倍。

一个起偏分束器用以将所述棱镜装置出射的所述返回光束对准光探测器。

9．用光束在光记录介质上读和／或写数据的光头中探测聚焦误差的方法，其特征步骤是

在由所述介质反射的返回光束的光路上放置一棱镜，用以将光束在一个方向上压缩M倍，同时在所述方向上把所述光束与聚焦误差相关的发散／会聚角增加M倍，从而将表示聚焦误差的电信号增强M^2倍。

10．权利要求9中的方法，进一步的特征步骤为：

提供一个具有内外光敏区以根据所述内外光敏区的光强差产生所述信号的光探测器。

11．用于在光记录介质上读和／或写数据的光头上的探测聚焦误差的方法，特征步骤是

在由所述介质反射的返回光束的光路上放置一棱镜，用以在一个方向上将光束宽度压缩M倍，同时在所述方向上把所述光束与聚焦误差相关的发散／会聚角增加M倍，从而将聚焦误差信号增强M^2倍：并且

由具有一处在两个外光敏区中间的一个条形内光敏区的光探测器产生所述信号，所述信号的幅值正比于所述内外光敏区光强之差。

12．权利要求11中的方法，特征在于所述区域在垂直于条形方向分割，以产生三个上光敏区和三个下光敏区，相互之间电绝缘，另一表示轨迹误差的电信号由所述上下区域光强差产生。

13．权利要求11中的方法，其特征是进一步调整聚焦透镜在光路中位置，以响应所述信号，保证在所述内区 探测到的光强等于在所述外区探测到的光强之和，从而消除所述聚焦误差。

14．一个用在有大量轨迹以存储数据的光盘上的光头，特征为提供平行光束的装置。

第一棱镜装置用以通过折射使光束成为圆截面。

包括一光束弯头和透镜装置的装置，通过它把圆截面光束对准在光盘上选定轨迹上。

第二棱镜装置。

所述第一棱镜装置有一个部分偏振分束表面，用以将光盘反射的返回光束的P偏振成分的一部分和所述返回光束的几乎所有S偏振成分对准到所述第二棱镜装置；并且

有一光探测器用以产生一响应所述返回光束聚焦误差的信号。

所述第二棱棱装置有一个部分起偏分束表面，用以将刚说过的光束的P偏振成分的一部分折射到所述光探测器，从而使得刚提到的部分导致返回光束在一个方向上压缩M倍，同时在所述方向上将与聚焦误差相关的所述光束的发散／会聚角增加M倍，从而将所述信号增强M^2倍。

说　　明　　书

利用棱镜增强光斑尺寸监测法探测聚焦误差

本发明涉及在光记录介质上读写数据的光头中聚焦误差的探测方法和装置，特别是改进的产生聚 焦误差信号的装置，该聚焦误差信号用作伺服系统的输入，其动作可保证光束在表面聚焦。

目前在光存储应用中所采用的散焦探测方法包括一个锐边，一个象散透镜或者一个临界角棱镜，这些技术需要对这些光学元件和对缝或分区光探测器做非常精细的校准。

已公布的欧洲专利ＥＰ０１６４６８７提出了一种探测方法，其中从光盘反射的激光束通过一物镜对准一棱镜，该棱镜将光束宽度在一个方向压缩Ｍ倍后，并将一椭圆截面光束传输到一锐边型聚焦误差探测系统。根据公式（２５），该应用据称 可将聚焦误差信号增大Ｍ倍。

１９８５年１０月１５日至１７日在美国华盛顿召开的光数据存储专题会议的文摘中有一篇Ｙａｍａｍｏｔｏ等人的文章（ＴＨＣＣ２－１），标题为"光刻尺度的设计构想"文章提出了一个探测与聚焦误差有关的远场光斑尺寸变化的六元件光探测器。

需要一种非常灵敏的聚焦误差探测方法，以相对较少的元件使聚焦误差信号明显增强并提供大的光束面积，使得只需在一个方向上对分区光探测器做不甚精确的校准。

为了达到这个目的，该发明提供了一套通过设置在从光记录介质

反射回来的返回光束光路中的棱镜在光头中探测聚焦误差的装置和方法。该棱镜在一个方向上将光束压缩M倍，同时在所述方向上将与该光束的聚焦误差有关的发散/会聚角增大M倍，从而可望将聚焦误差信号增强M^2倍。正如Yamamoto等人的文章中所示那样，聚焦误差差由包含内外光灵敏区的分区光探测器探测出来。光探测器从内外区光强之差中产生出指示聚焦误差的电信号。该光探测器的分区方式最好能使之可以提供轨迹误差信号。

图1，为表示该发明原理的示意图；

图2A和2B，表示了分区光探测器的两种优选的配置，它们都产生聚焦误差信号，其中图2B同时还可产生轨迹误差信号；

图3，表示按照本发明一个实施例用于只读、一次写入或相变光盘的光头；

图4，表示一个用于带有旋臂传动装置的光盘驱动器的实施例；

图5，表示用于磁光盘的实施例。

本发明的原理由图1作了最好的说明。二极管激光器10的输出通过一个圆形扩束/准直系统11产生一平行光束12。通过分束器13反射，光束12成为光束14。光束14通过透镜15聚焦到光记录介质的表面16上。当表面16处在透镜15的焦点时，由分束器13到透镜15的平行光束14向回反射后，并作为返回光束14，通过分束器13到达棱镜17，棱镜17将光束14折射成18，并对准光探测器19。光束18具有椭圆形的强度分布图形，其长轴为D短轴为A。棱镜17将光束14的宽度压缩M倍（M定义为D/A）成为折射光束18的宽度。

现假设表面16上的数据偏离焦点的量为δz。在该假设的条件

下，由表面16反射的光束14'通过透镜15以后以$\delta\vartheta$角发散，其中：

$$\delta\vartheta = D\delta z / f^2$$

其中f是透镜15的焦距

如果δz为负，则$\delta\vartheta$也为负，反束光束14'将会聚。以下分析考虑δz为正的情况下，但当δz较小时，对于发散或会聚光束14'，这一分析同样适用。

由棱镜17产生的折射光束18'具有发散角$M\delta\vartheta$，而在探测器19处的所述光束宽度A'由下式给出：

$$A' \approx A + 2 l M \delta\vartheta \qquad (2)$$

其中l是棱镜17到光探测器19的距离，

利用公式1，可得：

$$A' \approx A + 2 l M D \delta z / f^2$$
$$\approx A + 2 l M^2 A \delta z / f^2$$

或

$$A' / A \approx 1 + 2 l M^2 \delta z / f^2 \qquad (3)$$

由此可见，通过在从表面16反射的返回光束14'的光路中设置棱镜17，表征聚焦误差δz的波束宽度A的变化增强了M^2倍。M由棱镜17的顶角和棱镜材料的折射率决定。M可以做的任意大；但随着M增加，系统校准的容差将越来越小。单一棱镜17的实际最大值大约为M＝5；但几个棱镜可以串联起来使用，则最终的因子M就是每个棱镜M值的乘积。

如图2A所示，光探测器19由三个条形光敏区1，2，3组成，设I_1，I_2，I_3，分别为进入这些光敏区1，2，3的光所

产生的电信号，对于图2A的配置，令$S_1 = I_1 + I_3$，$S_2 = I_2$。令KA为中心光敏区2的宽度，这里K（≈0.25）选择得使得当光束14聚焦时$S_1 = S_2$。如果S_1'和S_2'是对应聚焦误差δz的信号，可以得出：

$$\frac{S_1'}{S_1} \backsimeq \frac{2(A'-KA)}{A'+A-2KA}$$

$$\frac{S_2'}{S_2} \backsimeq \frac{2(1-K)A}{A'+A-2KA}$$

和

$$FES = \frac{S_1'-S_2'}{S_1+S_2} = \frac{A'-A}{A'+A-2KA}$$

当$A' \backsimeq A$和$K = 0.25$时

$FES\ 0.67(A'/A-1) \backsimeq 1.31 M^2\ \delta z/f^2$

因而，作为例子，如果$M=5$、$l=50\,mm$并且$f=4\,mm$，则一个小的聚焦误差$\delta z = 0.5\,\mu m$可产生聚焦误差信号$FES = 0.05$。这样大的误差信号使得能够以高信噪比探测很小的聚焦误差。

信号I_1和I_3由20求和并加以放大，提供输出信号S_1，同时信号I_2由21放大提供输出信号S_2。信号S_1和S_2送往差分放大器22和求和放大器26，其输出送往除法电路28。除法电路

28的输出就是聚焦误差信号 FES。聚焦误差信号加在聚焦伺服控制系统23（图1）上。如图所示，系统23包含了用于调节线圈24中的电流从而可调整透镜15相对于表面16的位置的常规装置（未示出）。

光探测器的一个优选的配置如图2B所示，光探测器25包含6个光敏区1－6，可分别产生电信号I_1 －I_6 。聚焦误差信号为：

$$FES = \frac{S' - S_2'}{S_1 + S_2}$$

并且轨迹误差信号为：

$$TES = \frac{S_3 - S_4}{S_3 + S_4}$$

其中：$S_1 = I_1 + I_3 + I_4 + I_6$

$S_2 = I_2 + I_5$

$S_3 = I_1 + I_2 + I_3$

$S_4 = I_4 + I_5 + I_6$

利用轨迹误差信号调整轨迹误差的方式已是常用的，不构成本发明的一个部份。图2B包含在这里只是为了说明申请人的探测及校正聚焦误差的方法和装置可以适应象25那样能产生聚焦误差和轨迹误差两种信号的光探测器并可 与之结合使用。

如图 3所示，根据这一实施例该发明包含一特别适用于只读、一次写入或相变光盘的光头。激光器３０的发射光通过透镜３２成为平行光束，并通过棱镜４６的表面３４折射后变成圆形光截面。表面３４有起偏分束（ＰＢＳ）的涂层。光束３５通过一１／４波片３６到光束弯头机透镜４０，它将所述光束聚焦到光盘４２的选定轨迹上。由光盘４２反射回来的光束３５'通过波片３６返回并由棱镜表面３４反射为光束３７到达棱镜４６的表面４４。光束３７在表面４４的折射将所述光束的宽度由Ｄ到Ａ压缩了Ｍ倍并将该椭圆光束４７引向光探测器４８，光探测器最好按图２Ａ或２Ｂ分区。

如图 3所示，如果在光盘４２轨迹上的数据处于焦点上，则反射光束３５'将和光束３５重合，并且在光探测器４８处的光束宽度为Ａ。然而，如果光盘４２上的数据不在焦点上，则反射光束３５'相对于光束３５发散，并且如图 1所示，使得在光探测器４８处的光束宽度大于Ａ。由图２的说明，光探测器４８这时将产生一个ＦＥＳ；用适当的伺服装置（未画出）可根据这个ＦＥＳ调整棱镜４０相对于光盘４２上轨迹的位置，以满足将数据置于焦点上的要求。

这个实施例所需元件数可望较少。

图４Ａ和４Ｂ表示另一种用于只读，一次写入或相变光盘的光头的实施例。根据这个实施例，光头的大致指向平行于光盘５０上的轨迹。这种光头因而很容易用在具有旋臂传动装置的光盘驱动器上。激光器５２（图４Ａ）发射出经透镜５Ａ准直的光束，并被引向和通过一个无折射或反射的ＰＢＳ５６。通过ＰＢＳ５６的光束５８具有椭圆截面，其一个方向宽度为Ｄ而另一正交方向宽度为Ａ。该光束５８通过一１／４波片６０并对准一组合棱镜６２。在组合棱镜６２的第

一表面６４，光束５８变为圆形截面，而后经棱镜另一表面６６内全反射（ＩＩＲ）而反射至反射表面６８再出射到物镜７０，物镜７０将形成的光束７２聚焦在光盘５０上。光束７２经过光盘轨迹反射为光束５８'。光束５８'的截面再次成为椭圆的，通过ＰＢＳ５６的表面７４反射并引向光探测器７６，光探测器７６最好按图２Ａ或２Ｂ分区。

如图４所示，如果光盘５０轨迹上的数据处于焦点上，则反射光束５８'和光束５８重合，在光探测器７６处的光束宽度为Ａ。然而，如果在光盘５０上的数据不在焦点上，则反射光束相对于入射光束５８发散，并且如图１所示，使得在光探测器７６处的光束宽大于Ａ。由与图２相关的讨论，光探测器７６给出ＦＥＲ；根据这个ＦＥＳ用适当的伺服装置（未画出）调整透镜７０相对于光盘上轨迹的位置，以满足将数据置于焦点上的要求。

这个实施例要求棱镜６２的展宽／压缩比Ｍ和激光器５２的出射光斑形状匹配。

图５显示了另一种用于磁光盘光头的实施例。激光器８０出射光束由透镜８２准直，通过棱镜８６的表面８４折射后成为圆斑光束，然后对准光束弯头８８和物镜９０。表面８４是部分起偏分束表面，它将光盘９４上选定轨迹所反射的光束９２'中的Ｐ偏振成分的一部分和所述光束几乎所有的Ｓ偏振成分反射到棱镜９６的表面９８成为光束１００。表面９８也是部分起偏分束表面。表面９８将一光束１００的Ｐ偏振成分的一部分折射到一个伺服光探测器１０２成为光束１０１，该探测器最好按图２Ａ或２Ｂ分区。这个折射使得光束１００任一个方向上的宽度从Ｄ到Ａ被压缩Ｍ倍。表面９８还将

光束１００的Ｐ偏振成分的一部分和光束１００的几乎全部Ｓ偏振成分引向Ｗｏｌｌａｓｔｏｎ（渥拉斯顿）棱镜１０４、会聚棱镜１０６和数据探测器１０８，形成光束１０３。Ｗｏｌｌａｓｔｏｎ棱镜探测磁光盘数据的性能已为本行业周知并不构成此发明的一个部分。

如图５所示，如果光盘９４轨迹上的数据是处于焦点上，则返回光束９２＇和原光束９２重合，在光探测器１０２处光束宽度为Ａ。然而如果光盘９４上的数据不在焦点上，返回光束９２＇将相对于原光束９２发散，并且如图１所示，使得在光探测器１０２处的光束宽度大于Ａ。由关于图２的说明，光探测器１０２将产生ＦＥＳ，并根据该信号用一适当的伺服装置（未画出）调整透镜９０相对于光盘９４上轨迹的位置以满足将数据置于焦点上的要求。

可以看出，在图３－５所示的每一种配置中，和以前的方法不同，聚焦误差信号可望增强M^2倍。

尽管本发明是参照其优选实施例作　展示和叙述的，精于本行业的人应当明白在形式和细节上可以做出多种变化，而并未超出本发明的思路和范围，因此除了权利要求中指明，本发明是不受它们局限的。

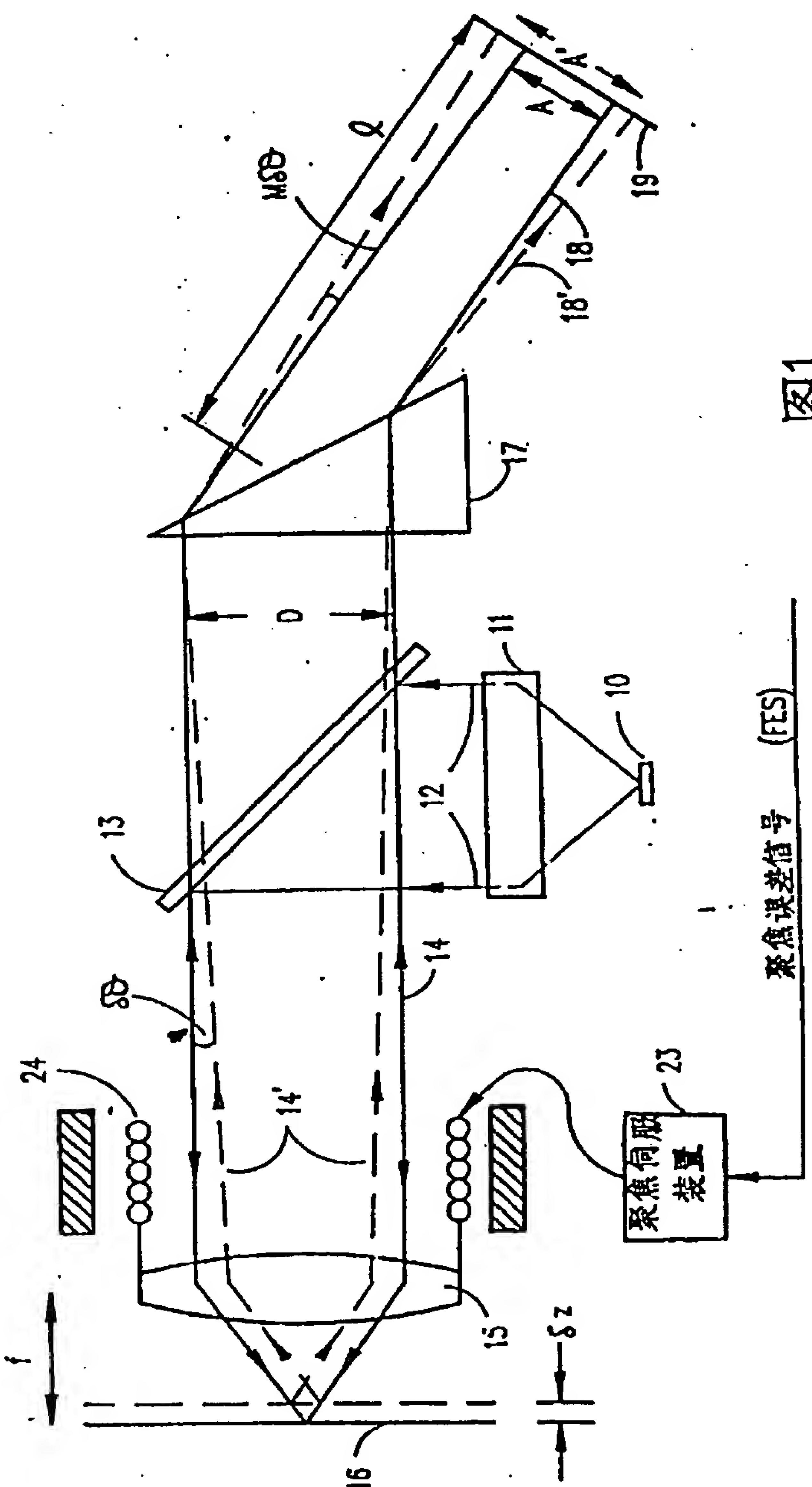

A
A'
l
MSD
19
18
18'
17
D
11
10
13
12
14
14'
24
23
聚焦误差信号 (FES)
聚焦伺服装置
15
16
f
δz

图1

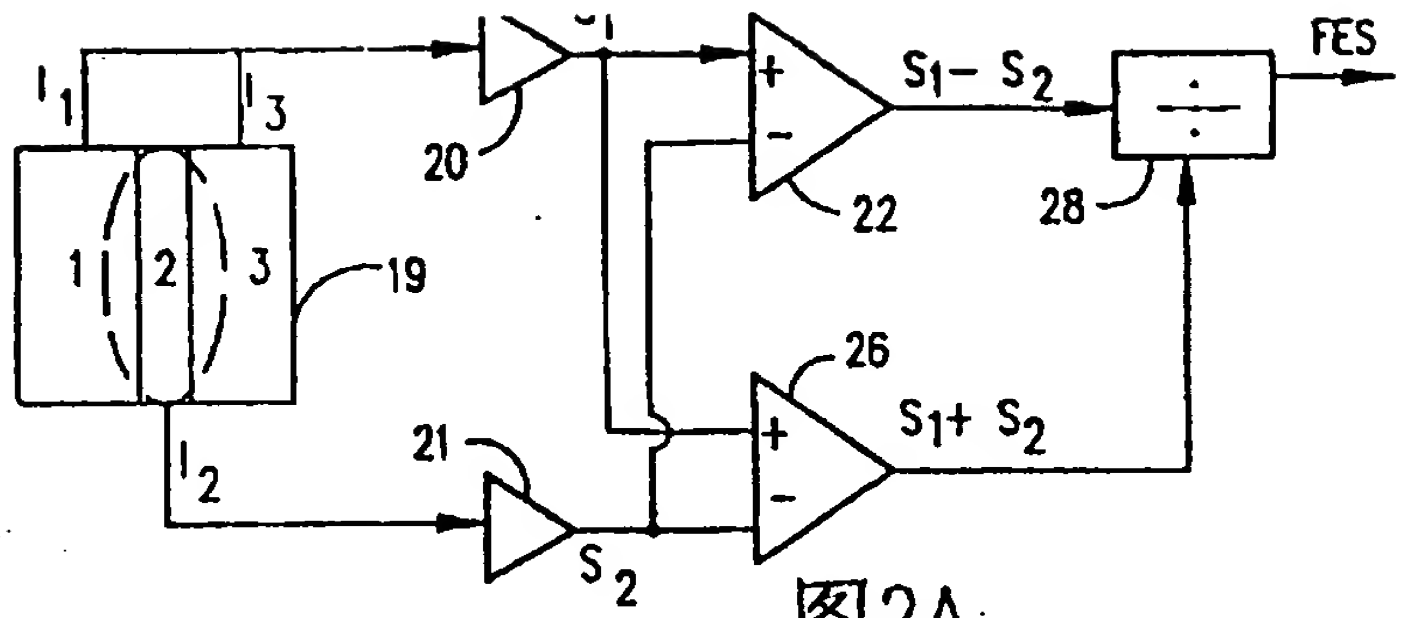


图2A

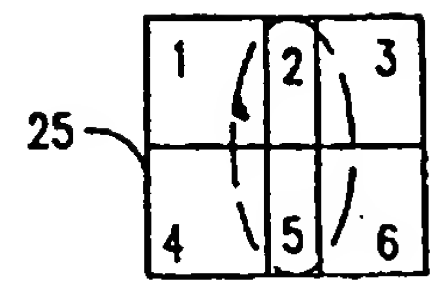


图2B

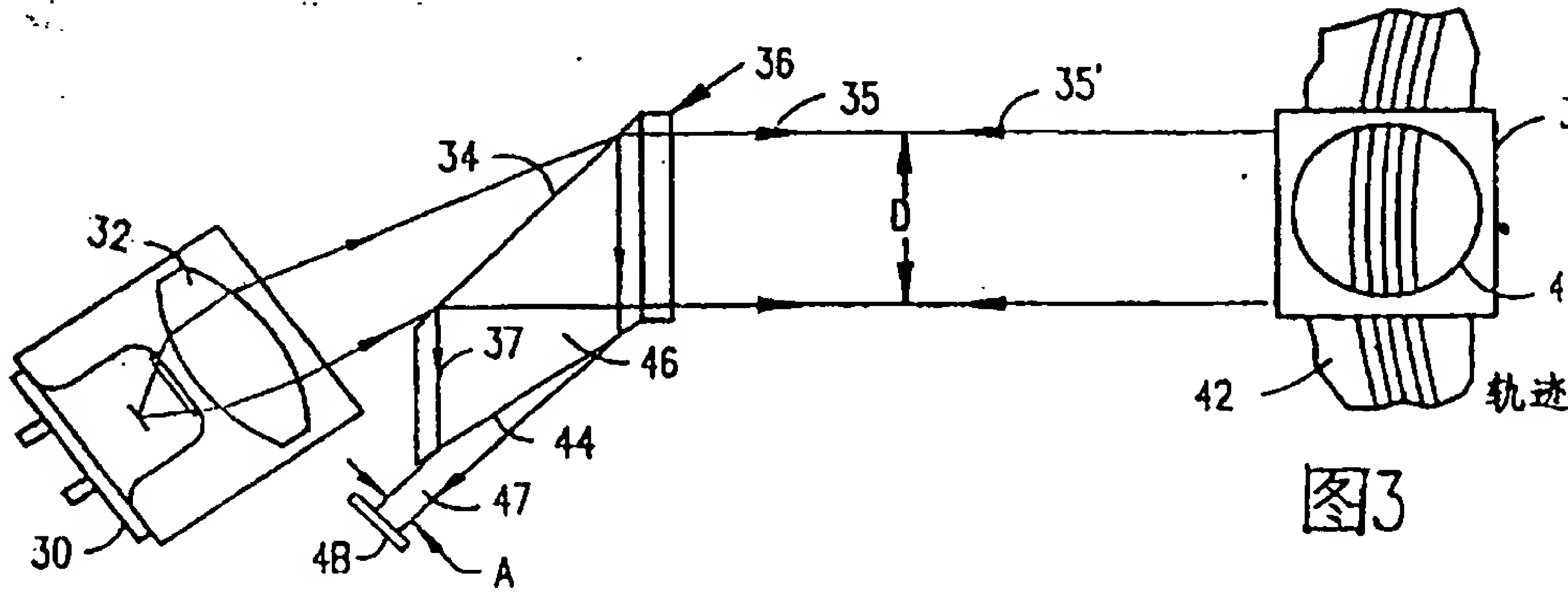


图3

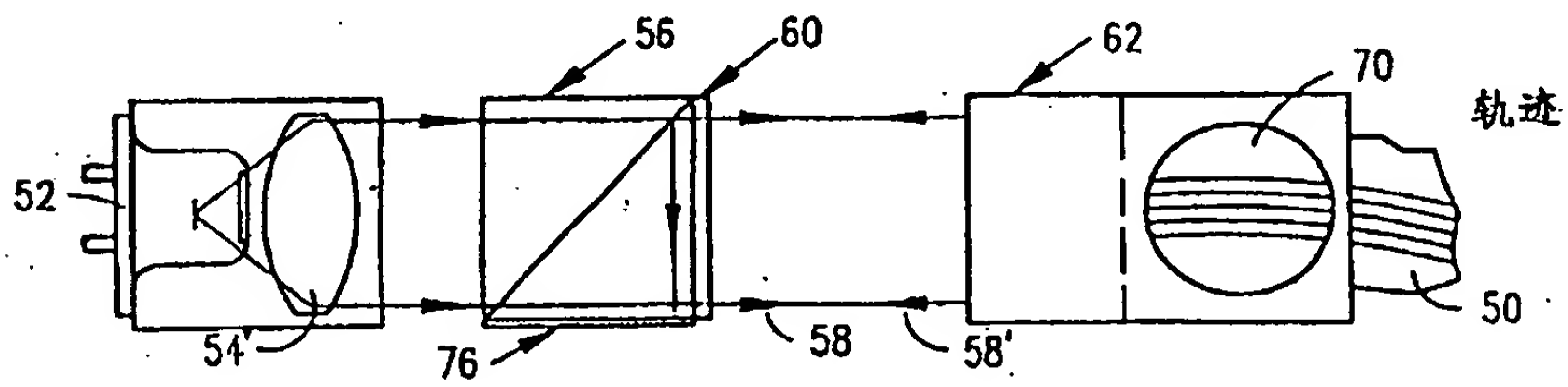


图4A

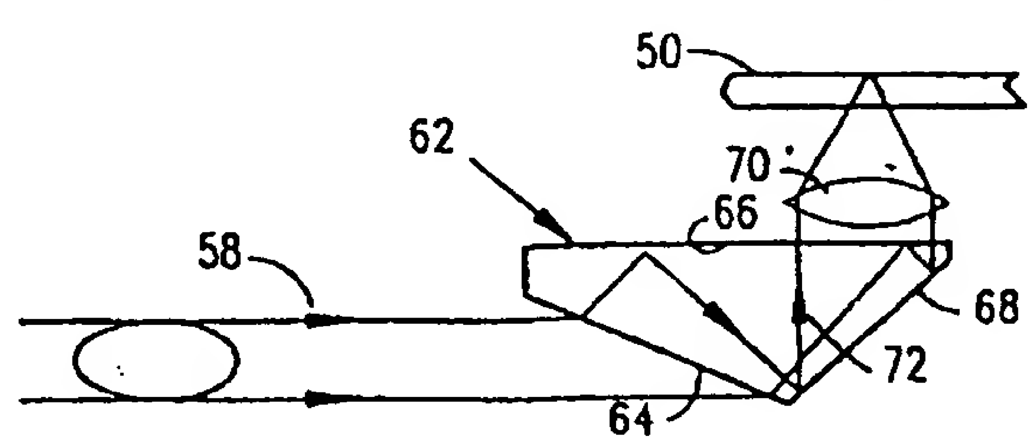


图4B

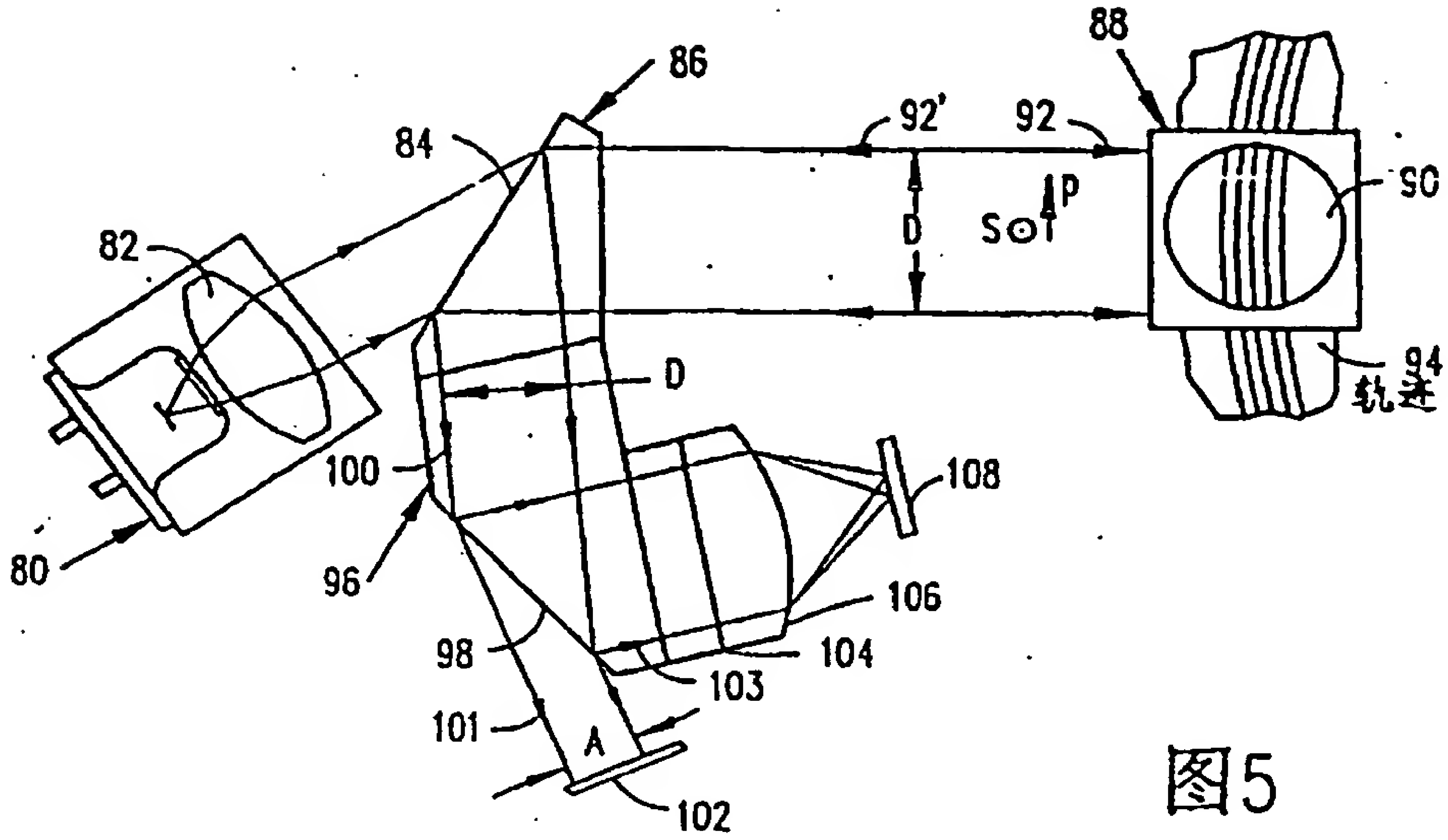

86
84
92'
92
88
82
D
SO
P
90
D
100
108
80
96
106
98
104
103
101
A
102
94
轨迹

图5